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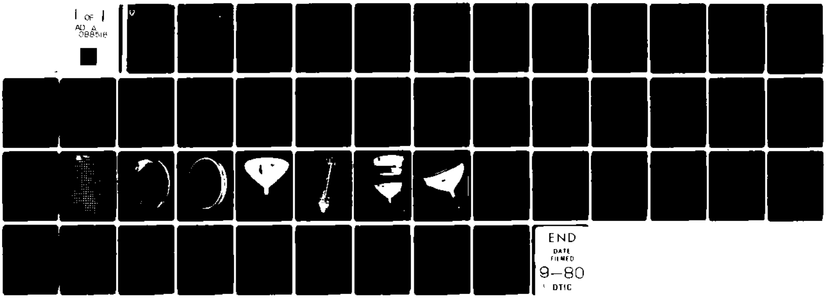
UNCLASSIFIED WO-373 DELET-TR-74-C-0605-F NL



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AD-A088 285 SC

Research and Development Technical Report

DELET-TR-74-0605-F

AD A088518

PHOSPHOR-PENETRATION COLOR CATHODE-RAY TUBE FINAL REPORT

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JUNE 1979

Final Report for the Period 1 July 1974 to 30 June 1979

DISTRIBUTION STATEMENT

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PREPARED FOR
Electronics Technology & Devices Laboratories

ECOM

US ARMY ELECTRONICS COMMAND FORT MONMOUTH, NEW JERSEY 07703

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: DELET-TR-74-C-0605-F	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): PHOSPHOR-PENETRATION COLOR CATHODE-RAY TUBE	5. TYPE OF REPORT & PERIOD COVERED: Final Report 1 July [redacted]74 [redacted] 30 June [redacted]979
	6. PERFORMING ORG. REPORT NUMBER: WO-373
7. AUTHOR(s): Emil Sanford	8. CONTRACT OR GRANT NUMBER(s): DAAB07-74-C-0605
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Thomas Electronics, Inc. 100 Riverview Drive Wayne, NJ 07470	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA Task No. 1S7 62705 AH94 D1 04
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Electronics Research & Development Command Electronics Technology & Devices Laboratory ATTN: DELET-BD, Fort Monmouth, NJ 07703	12. REPORT DATE: June [redacted]79
	13. NUMBER OF PAGES: 39
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Phosphor-penetration
Color-CRT
Isolation Mesh

16-in.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In a 16"-diameter voltage-penetration-type color-CRT a metallic mesh is mounted in proximity to the phosphor layer in order to isolate the switched high-voltage fields applied to the phosphor-screen from the magnetic deflection zone. Electron-optical analysis predicts the degree of geometric distortion over the switching range of 10-20 kV. Some correction means are suggested. Objective goals for resolution and brightness are quantitatively examined. The mechanical design is also described.

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1. Introduction

The basic design and development of this phosphor-penetration color cathode-ray tube was prescribed by the USAECOM Technical Guidelines BD-6 document of 21 June, 1973. See the addendum attached to this Final Report.

1.1 The particulars of the bulb-geometry were complied with by using the Corning Glass Works bulb type J127E1. This has a 16-inch-diameter glass faceplate. The faceplate is available in two different radii of curvature and with differing optical transmission. The faceplate chosen for this program has a 40-inch inside radius and a light-transmission of 85%.

The entire bulb is illustrated in Figure 1. It was purchased in two pieces, with the separation indicated by the Bulb Closure Line. This two-piece glass assembly is subsequently closed by a (solder-glass) frit seal.

1.2 The primary goal of this program was interpreted to be the attainment of a voltage-switched color-change of the display "without measurable effect upon the deflection-sensitivity". This technical performance was to be attained, as discussed in the early stages of this program, by the insertion of a semi-transparent metal shield between the HV-switched phosphor-screen and the magnetic deflection-yoke region. The "isolation mesh" assembly, as sketched in the Figure 2 drawing of the Mesh-ring frame, occupied the bulk of early development.

1.3 For the semi-transparent shield a custom-made, two-mil thick, stainless-steel mesh was purchased from Buckbee-Mears Corp. It is approximately 50% transmissive. To achieve the working resolution requested in the Guidelines, this mesh has a pitch of 140 lines/inch,

with approximately 5-mil apertures. See Figure 3.

1.4 Initially it was agreed to contour the mesh to a convexity co-spherical to the 40-inch radius of screen-curvature. Screen-to-mesh separation was assigned a 0.5-inch gap.

The mesh-ring frame construction order was awarded to C. B. Kaupp and Sons of Maplewood, New Jersey. They completed the ring frames in good form, but the mesh-contour-doming could not be successfully achieved. Note the mesh-wrinkles visible in the photograph of Figure 4. In due course this technique was abandoned, and a test was conducted with a flat-stretched mesh welded to the rim of the frame. This became the standard mesh-frame assembly. Later knowledge confirmed that this technique was satisfactory.

1.5 In a standard process the J127E1 upper bulb assembly was screened with voltage-sensitive, penetration-type phosphor. This 16-inch-diameter panel-section is pictured in Figure 5. The mesh-frame is clip-mounted via three support springs into the bulb-funnel assembly of Figure 6.

The panel of Figure 5 is thereupon frit-sealed onto the funnel-section, and the electron-gun of Figure 7 is flame-sealed into the funnel-neck. The base is attached after the CRT is evacuated and sealed-off. These assembly plans are pictured in Figure 8.

1.6 The appearance of the finished 16M100 CRT is shown in Figure 9. Its manufacturing assembly outline dimensions and the location of its electrical terminals are detailed in Figure 10. The bulb-geometry remained unchanged throughout the entire program.

2. Optical Design

The faceplate is 85 percent transmissive, and the shield-mesh is about 50% transmissive. Thus the electron-beam current leaving the electron gun has to be 2.35 times larger than required by the basic phosphor current-efficiency.

2.1 It was decided early that the red-to-green color-shift would be limited to a 2-to-1 voltage-change. It was eventually established by visual observation that RED should be generated by 8 kilovolts; thus GREEN would be energized by 16 kilovolts.

2.1.1 These materials are designated the PX178 phosphor and the PX183 phosphor for reference.

2.2 The latter green luminescent phosphor exhibited a screen efficiency of approximately 8 lumens/watt. Care was needed to verify the actual electron current at the phosphor screen.

2.2.1 For the prescribed area of brightness-measurement of 10x10 inches, equal to 0.7 square foot, each watt of excitation produced 11.4 foot-lamberts through the 85% transmissive faceplate. At 16 kilovolts, the screen current for one watt is 63 micro-amperes; the beam-current required is twice as great, or 126 uA, because of the mesh-transmission.

2.3 The Guideline specifies 1000 adjacent spots per screen diameter minimum. At 14 inches of screen diameter the spot-size must be .014 inch. The mesh-pitch of .007 inch does little to diminish this figure.

2.3.1 To achieve the specification figure of 100 foot-lamberts of green brightness, a peak electron-beam current of 1100 uA would be required.

2.3.2 The maximum electron-beam current produced by the gun of this CRT, at a (gun + mesh) potential of 16,000 volts, is 325 uA. As this is only 30% of the screen current required, the peak green brightness of this CRT is approximately 30 foot-lamberts.

2.4 The general theory of electron-energy absorption in a three-layer penetration-phosphor screen is illustrated in Figure 11. Assuming equal density of each layer, note that the 8 kV electrons penetrate the first 25% of screen-depth, i.e.; the red-emitting phosphor. Following this is the "killed green" neutral layer. The final layer is active green-emitting phosphor.

2.4.1 In practice electron-penetration of the red layer is not precisely complete at 8 kV, nor is penetration of the green complete at 16 kV.

2.4.2 Note that "red absorption" is more compactly defined compared with the "green absorption" spread. It is necessary to utilize a "killed" phosphor neutral zone between the emission layers.

2.5 At the CRT faceplate the maximum color-display diameters are not the same.

Max. Red image = 14 3/8" diameter approx., and

Max. Green image = 14 3/16" diameter approx:

in Mode II operation. This differential size is due to an electron-optical trimming at the inside diameter of the mesh-frame assembly of 13 1/4". The transit angle between the mesh and screen is larger for Red, owing to refractive bending of the beam.

This size-difference is intrinsic; it cannot be avoided by electronic compensation. However, the extra red border could be mechanically masked.

2.6 Stainless-steel etched mesh in two-mil thickness with optical transmission of 80% is available in 6x6 inch size.

It appears that this high-transmission mesh-material may be manufactured in the near future, but the inter-aperture resolution may not be better than 1000 LPI.

However, etched stainless-steel mesh in one-mil thickness could have a better T.R. factor=(transmission x resolution).

3. Mechanical Design

The general details of the fabrication of the 16M100 CRT are noted as follows:

3.1 The J127E1 bulb is purchased in two parts, a panel and a funnel section. However, a number of add-on operations are required.

3.1.1 The panel despite its large thickness in side-section, has a J121 contact-button flame-sealed in at 7/8 inch from its seal edge.

3.1.2 The panel-section contains a complete annular band of dag conductor for good resistive contact to the metallized phosphor-screen.

3.1.3 The funnel-section has two additional J121 buttons flame-sealed into its side-section. This was an anticipated corrective means for cancelling the screen-section refraction errors. By means of "Aquadag" bands at each J121 button, a voltage-gradient between bands would compensate the electron-beam path for a normal approach to the mesh electrode.

3.1.4 This corrective scheme was insufficient in effect; the correction zone is too short, and the flat mesh exaggerated the angle to the normal.

3.1.5 An electron-gun is flame-sealed into the neck-area of the funnel. The bulb-assembly of Figure 8 is then evacuated at high bake-temperatures.

3.2 The panel and funnel rim edges, at the bulb-closure line, are fine-ground to facilitate a frit-seal; this is similar to T-V CRT technology.

3.2.1 The mesh-frame is mounted, via spring-loaded arms, onto the funnel-section, not on the panel. The advantage of this assembly means is the further separation of the mesh-electrode from the screen-electrode. It minimizes the voltage-flashover problems, or leakage, which are likely if the support-studs were emplaced on the panel.

3.2.2 Preliminary to frit-sealing, the mesh-ring frame-assembly with its three radially mounted springs is inserted at the top end of the funnel. Previously to this step, another frame was jigged to emplace three color-CRT studs via a first frit-seal bake. The mesh-frame springs clip upon the studs in the funnel, thereby firmly supporting the mesh-frame. Finally the (solder-glass) fritted panel is mated to the funnel and frit-sealed. These are commercial T-V CRT techniques.

3.3 Figure 2 is a cross-section drawing of the mesh-ring frame assembly. Essentially it is a short cylinder of 14 1/4" diameter, twist-stabilized by a rim at each edge. It is of "S"-section shape.

The upper rim has a 13-1/4" I.D.; in this 1/2" annular zone the isolation-mesh is attached. It does not appear to be necessary to overlay this zone with a metal cover.

On the other side of the frame an annular ring, 14-1/2" O.D. by 11" I.D., is welded to the lower rim. This aids frame-rigidity and trims electron-beam overscan. This eliminates an "electron-splash" from the high sidewall of the frame.

3.3.1 The top-side frame I. D. of 13-1/4" defines the maximum display size on the phosphor-screen at about 14" O.D.; an inscribed

square of 10X10 inches per side just fits the circular area of the phosphor-screen, as a test zone.

3.3.2 The isolation-mesh is of 2-mils thickness with webs of 2-mil minimum width as a practical limit of producibility. A serious attempt was made to "dome" the mesh-contour to a 40-inch radius-of-curvature.

The weighted frame with mesh attached was placed over a section of a spherical form and was heated, for hours, to a temperature of 800 degrees Celsius. It was contoured but badly wrinkled; see Figure 4. Also the out-board mounting-springs became annealed and lost their temper.

3.4 This problem was resolved by rim-welding a flat-stretched mesh, heated under a 250-watt lamp, onto its frame. This assembly weighed 1/3 kilograms. Each spring had a supporting strength of 1.5 kilograms

3.5 The final sub-assembly of the 16M100 CRT is the TEI type 1039-5 electron-gun. It is adopted from another military (AWACS) program. It utilizes the 14-pin color-TV stem with the separated #9 pin; to this is fed the (high) focus-voltage, up to 3000 volts.

The CRT stem plus glass tip-off is finished with a cemented plastic keyway-base.

4. Electron-Optical Design

As noted in the Introduction of this report the general specifications for this CRT were fixed by the Guidelines. In particular the co-spherical isolation-mesh is the primary internal member of this penetration-phosphor color-CRT. Notice, via Figure 8, that the mesh is

closely spaced to the phosphor-screen; it is within 1/2 inch.

4.1 It is evident that the internal voltage-geometry of this 16M100 CRT is virtually identical to that of a standard CRT with a monochrome phosphor and no internal mesh-shield. As such, this color CRT is an operational retrofit to other tubes using the J127 bulb as a basic envelope.

4.1.1 Except for the extra dag bands, seen in Figures 6 & 9, which may have special voltages applied for internal refraction of the scanned electron-pattern, this is an electronically-matched assembly. The operational performances of the electron-gun and the magnetic deflection yoke are no different from those of established design. The CRT has an unipotential interior and an unipotential (Einzel lens) focussing electron-gun.

4.1.2 The special difference in this CRT is located at the inter-space gap between the mesh and screen when the gap-voltage is not zero.

4.1.3 Figure 12 is a simple drawing of any radial cross-section of a domed mesh or a flat mesh. This difference is noted because of the imposed change from the initial mesh-contour. With a (peak) deflection-yoke scan-angle, the radial scan height on the mesh can be located.

4.1.4 The radial scan-height on the screen, from the mesh to the phosphor-screen may be determined in terms of the differential angle e, see Figure 13. Note that W_2, W_3, or W_4 is added to H_1 or H_2, as the case may be. Note too, there is a differential deflection-size change, labelled "depositioning", for a plus vs minus voltage-gradient from mesh to screen.

4.1.5 Figure 14 is the more general case, for a display-screen inside radius-of-curvature of R_1 and a mesh radius-of-curvature of R_2. A later discussion will establish that $R_2 < R_1$, and that a flat mesh is a very acceptable design.

The point is made that the interspace gap l, which varies

from l_o on axis to g at max. screen-diameter, has a compensatory function against scan-angle.

4.1.6 It was originally assumed that the mesh would be co-spherical with the screen. However, test results made evident that color-switch "depositioning" could not be compensated with a single value ($\Delta V4$ or $\Delta V234$) of auxiliary switch-voltage. *It is obvious that a fixed value of correction voltage is attractive for circuit operating simplicity.*

Since depositioning (ΔH) of Figure 14 is a direct function of the interspace (l), it was concluded that l had to diminish from l_o to g. A sample calculation is included in Figure 14.

4.1.7 A graph of the magnitude of depositioning due to interspace refraction is diagrammed in Figure 15. Very simply, Mode I or Mode II refractive depositioning, as in Figure 13, is plotted in Figure 15.

The phosphor screen of the 16M100 CRT may be operated at a higher voltage than the mesh $V_5/V_4 \rightarrow 2$, or at a lower voltage than the mesh, $V_5/V_4 \rightarrow 0.5$ to change the display color.

The depositioning resultant (ΔH) is small, being an approx. 1% dimension change. In theory, it could be made still smaller by diminishing the interspace or by diminishing the beam-angle with respect to the normal to the mesh.

4.2 Color-Switching Compensation

The PX183 color-screen changes color according to the beam-voltage level. It is red at 8 kV, yellow at 12 kV, and green at 16 kV. As discussed above, there is a small size-change as the colors in the display image are changed. There is an operating technique that compensates the size change or depositioning.

4.2.1 Intrinsically, the green image is always smaller than the red. All that is needed for a size-match is a small increase in the deflection-magnitude synchronous with the green color operation.

4.2.2 Two anode-voltage operating modes are illustrated in Figures 16a and 16b. These define the up-voltage color-switch as No. I Mode, wherein the mesh-voltage on terminal A_4 is synchronously switched down by about 400 volts, from 8.0 kV to 7.6 kV, as the green color is attained by raising the screen-terminal A_5 from 8.0 to 16.0 kV, which also creates interspace refraction.

4.2.3 In Figure 16b the down-voltage condition now creates the interspace refraction. The red color image becomes larger as the beam-voltage has been decreased from 16.0 to 8.0 kV. In this No. II Mode the size-increase is compensated by synchronously raising the mesh-terminal A_4 voltage by about 800 volts, from 16.0 to 16.8 kV.

4.2.4 The larger red image is reduced to match the green image by raising V_4 voltage so as to decrease deflection-sensitivity. To a good approximation this varies as the inverse square of the appropriate anode voltage. The synchronously switched difference-voltage is:

$$\Delta V_4 = \frac{V4}{.5}\left[\left(\frac{H+\Delta H}{H}\right)^2 -1\right]$$

Because the compensation voltage is applied to a fractional part of the anode electrode, which is the mesh-terminal A_4 alone, it has reduced effectiveness. Were it applied to all anodes = $A_2+A_3+A_4$ it would be approximately twice as effective. $\Delta V_{234} = V_{234}\left[\left(\frac{H+\Delta H}{H}\right)^2 -1\right]$

4.2.5 By similar considerations, a green-to-red image match in size is effected by a very small change in the deflection amplifier (s). Instead of a high-voltage switch, generating V_4, a ground-level switch can readily

diminish the deflection magnitude during the red-image interval by approximately a 1% reduction of gain in the deflection amplifier (s).

This appears to be an alternative approach, but it has not been verified by actual test during this program.

4.3 Single Value of Compensation Voltage

Experimental data disclosed that color-image depositioning is not compensated by a single value of ΔV_4 volts. A plot of ΔV_4 vs radial scan position shows variations. Typically a flat mesh mated to a 38" radius-of-curvature screen, with $l_o \approx 1.0$ inch and $g \approx$ 0.4 inch, sets ΔV_4=850 volts at one-inch scan and resets Δ V4=500 volts at seven inches of scan. These data apply to the 16M100 CRT as delivered.

4.3.1 Computing the ΔV_4 compensation volts for a flat mesh and flat screen, or co-spherical mesh and screen, always results in a rising value of compensation voltage against radius. It became apparent that the mesh is desirably flatter (of larger radius-of-curvature) than the screen; an optimum value could be found.

4.3.2 The space at the edge of the screen = g; it is smaller than l_o , but it could not be too small; at least 8000 volts had to be safely supported across this gap. The correct compensation value for l = g at the screen edge, where H=Hm, is found by proportioning the larger ΔH at H_m to the smaller ΔH at H near screen center.

4.3.3 Starting with a flat (stretched across the frame) isolation-mesh, a contoured screen is axially spaced for $l = l_o$ and for g, as shown in Figure 17. Trial calculations for tabulated values of H=1,2,3...7 inches, via the expressions in Figures 12, 13, etc., generate a set of ΔV_4 numbers. When these ΔV_4 volts are virtually at a constant value the

matching contour has been found.

For a flat mesh and screen the compensation voltage at maximum radius ranges to approximately twice its paraxial value.

4.3.4 It is a simple concept to contour the screen so that its initial value is

$$l_o = 2\ g \text{ and } R \approx \frac{(H\ max)^2}{2\ g}$$

which gives the matched contour of the screen for a constant value of ΔV_4.

4.3.5 The following tabulation compiles the axial spacing conditions for a representative list of screen-contours:

R	l_o	ΔV_4
25	2.0	1500
40	1.225	900
60	.817	600
100	.490	370
150	.327	240

V_4=16000 volts
H max = 7 [illegible]es.

4.4 Anode Capacitance

Color-switching speed is limited by the current-magnitude that the electronic switch can furnish; 8000 volts must be changed between red and green display, across approximately 112 picofarads.

4.4.1 The co-spherical mesh-to-screen gap in the early crt had a measured value of 146 pf at A_5 (screen terminal). The faceplate capacitance at 0.5 inch from the mesh computes to about 130 pf. The capacitance values of all the 16M100 color crt's are screen-surface sensitive to nearby objects.

4.4.2 The final version of the 16M100 crt had a larger average gap from mesh to screen of more than 0.5 inches. All of the anode terminals were measured for capacitance as follows:

A_5,	Phosphor screen	=	112 pf
A_4,	Isolation mesh	=	141 pf
A_3,	Funnel sidewall	=	58 pf
A_2,	Electron gun	=	80 pf
A_1,	Static Focus	=	5 pf

4.5 Display Resolution

A working objective in this crt is 1000 resolvable scanning lines. For the useful screen diameter of 14 inches this requires a line-width of 14 mils.

4.5.1 By inspection and electron-gun analysis the following list tabulates each kind of resolution-limiting factor.

A. Phosphor grain size ~ 3 mils
B. Mesh aperture pitch ~ 7 mils
C. Focus lens aberrations ~ 5.6 mils
D. Electro-Opt. image ~ 6.3 mils
E. Space-charge spread ~ 8.5 mils

By RMS summation of these distortions the line-width limit is 14 mils. This is achieved for an electron-beam current of 325 uA.

4.6 Maximum Screen Brightness

The PX183 phosphor with 16 kV excitation has a working screen efficiency of 8.4 lumens per watt. On the square 10 x 10-inch raster display about 30 foot-lamberts is the attainable maximum brightness. At a substantially increased drive the 16M100 crt produced 45 ft. lamberts at 700 lines resolution.

4.6.1 Deflection defocussing is observed using a conventional commercial deflection yoke. At the max. electron-beam current, in the Mode II condition, the focussed line-width enlarged by a factor of 1.7 x at $\pm$ 6 inches from screen-center. This is well corrected by refocus of the beam with approx. +400 volts; A_1 terminal is changed from 2300 to 2700 volts, approx.

4.7 Moiré

Interference fringes are possible because of close proximity of mesh to phosphor-screen. A near match of raster scan-line pitch to the mesh pitch can generate moiré.

4.7.1 In this crt the scanning height had to be substantially smaller than the screen-diameter. Line-to-line compression to more than 100 per inch did indeed show interference fringing.

4.7.2 Rotating the crt and mesh relative to the scan-pattern by 45 degrees virtually eliminates the moiré display.

4.8 Display Color Values

Two phosphor-screen types are incorporated in the finished 16M100 crts, samples #3 and #4. These were measured for their color coordinates at a moderate brightness level.

4.8.1 Sample #3 contained phosphor Type PX178 (Thomas ident.); this is essentially a "killed" P1 green admixed with P22R red, a rare-earth phosphor. Its color-range is printed on the Kelly chart of Figure 18.

4.8.2 Sample #4 is a dual mixture of "killed" P1 green plus P22G green and a rare-earth P22R phosphor. Its color and luminescent performance are shown on Figure 19.

4.9 Secondary Emission Effects

In the 16M100 crt the scanning electron beam impinges the semi-transparent isolation mesh and the phosphor-screen at high voltage. Low-energy secondary electrons are liberated, and these migrate to the nearest more positive electrodes. Reflected primary electrons are not considered.

4.9.1 As an example, the operating crt is driven to a total anode current of 300 μA at A_2=A_3=A_4=A_5=16000 volts. This is the cathode emission-

current, too.

With A_5 reset to 15,500 volts the electron-beam current divides to 270 μA at A_4 and 10 μA to A_5. With this small screen-terminal current the raster brightness measured 24 foot-lamberts.

When the A_5 terminal is raised (beyond A_4) to 16,500 volts, IA_4=90 μA, IA_5=190 μA, and the screen-brightness = 26 foot-lamberts. Despite the 19-fold increase in A_5 terminal current-flow the actual change in phosphor-screen excitation is negligible.

4.9.2 As a matter of fact the electron-beam current is 280 μA in both cases. Approximately 47% passes thru the mesh (A_4 terminal), and 132 μA to the screen (A_5 terminal). This input is about 2 watts into 0.7 ft.,^{2} producing 24 ft.-lamberts, which equates to about 8.4 lumens/watt of real-power screen efficiency.

4.9.3 It is thus apparent that color-switching can force a dynamic current exchange between A_5 and A_4 terminals. In Mode II the red color-select at 8000 volts below the A_4 terminal may even show reverse current; this can create operating difficulties in the H-V power source. With green color-select at 16,000 volts there can be a surge of current as the A_5 terminal collects most of the electron-beam current.

To alleviate this condition, the A_4 terminal voltage may be set slightly higher, such as 16,500 volts. As a result the screen-current continues as a small, and nearly constant, fraction of the total anode current.

4.9.4 Thus it is recommended that the isolation-mesh via A_4 terminal be utilized as the secondary-electron sink in the operation

of the 16M100 type of crt. This is also applicable for the electron-gun voltage at the A_2 terminal; keeping these electrodes at the highest potential ensures the maximum level of electron current in the focussed electron beam for the brightest display.

5.0 Reliability Considerations

No specific environmental testing is available as a formal part of this program. It is warranteed that the 16M100-type crt will pass the appropriate tests for crts specified in MIL-E-1.

5.1 The electron gun is the same type established in the 19M45 crt of the (military) AWACS Program. Shock and vibration qualification has been conducted.

5.2 The isolation-mesh frame-assembly is the novel addition to this crt. For this unit the established commercial design techniques of color-TV shadow-mask tubes have been adopted. It should be especially noted that, in reference to Paragraph 1.4, the interspace of the isolation-mesh to the phosphor-screen is not at all critical. Any small displacement or motion will not affect the displayed color and will only slightly affect the displayed geometry.

5.3 The glass bulb is a standard Corning Glass Works product. As such, the design is capable of withstanding a 45 pound pressure-test. In the 16M100 crt, there is one added J1-21 button on the panel and two added J1-21 buttons on the funnel.

5.4 Useful operating life of the 16M100 crt is predicted to be typical of industry standards. There are no unconventional materials or techniques utilized in its fabrication.

5.4.1 The mesh-frame assembly is of stainless steel. The glass bulb

is of the G-12 type. Gettering is applied above the electron gun. A routine evacuation-bake cycle processes this bulb assembly.

5.4.2 The panel-funnel sections are solder-glass sealed via the well-established frit-seal technology.

6.0 Conclusions

The 16M100 cathode-ray tube, with the PX183 color-phosphor and the isolation mesh-frame assembly, has succeeded in meeting the objectives outlined in ERADCOM'S Technical Guidelines BD-6.

6.1 It meets the specifications of mechanical size, electrical operating conditions, and optical output values in all respects but one. Maximum brightness level of the green color is only one-third the desired goal of 100 foot-lamberts.

6.2 The adjudged primary goal, "in which the colors in the display can be changed at will by the voltage applied to the phosphor-electrode alone, without measurable effect upon the deflection geometry, etc." has been realized to the fullest practical value.

The slight dimensional change, of about 1% magnitude, for the 100% color change is barely visible. By comparison to other voltage-penetration color tubes, whose pattern-size, shape, and focus have to be radically compensated, this crt is operationally stabilized.

6.3 The 16M100 cathode-ray tube fulfilled its design goals in a straight-forward and uncomplicated manner. This is favorable for operational reliability.

7.0 Recommendations

The color cathode-ray tube with the specific isolation-mesh feature is so superior for color image congruence that it warrants

further development. Other single-electron-gun type color-tubes, such as the "Chromatron" or "Apple" (beam-indexing) systems, require elaborate gating or switching circuitry. Three-gun TV color-tubes exhibit low-resolution images and require critical convergence techniques to preserve color purity.

The phosphor-penetration, isolation-mesh color-tube can be further advanced by:

7.1 Improvement in the phosphor-screens whereby color-range and selectivity versus penetration voltage is better resolved. Utilizing three primary color phosphors is a desirable possibility.

7.2 The isolation-mesh has only one task in the electronic operation of this type of color cathode-ray tube. It is a voltage-gradient shield. As such, it may be fabricated with mesh-transmissions approaching 80%, particularly in the flat mesh-frame assemblies. Beam-current efficiency is correspondingly improved.

7.3 Larger-diameter cathode-ray tubes, such as the popular 23-inch size, are readily adapted to this multi-color scheme of operation.

8.0 Publications, Reports, and Conferences

8.1 Phosphor-Penetration Color-Shift CRT with Invariant Deflection and Focus, 2-6-74. Emil Sanford, Thomas Electronics, Inc.

8.2 Technical Proposal for U.S. Army Electronics Command, Request Number DAAB07-74-Q-0322. Peter Seats, Thomas Electronics, Inc. 5-15-74.

8.3 Technical Discussion at Thomas Electronics, July 10, 1974 between Messrs. Munsey Crost, Irving Reingold, ECOM Fort Monmouth, New Jersey, and Messrs. Peter Seats, Emil Sanford, Thomas Electronics,

Inc. Wayne, New Jersey.

8.4 Administrative discussion at ECOM, Fort Monmouth, New Jersey, by H. A. Ketchum, Thomas Electronics, Inc., June 28, 1974.

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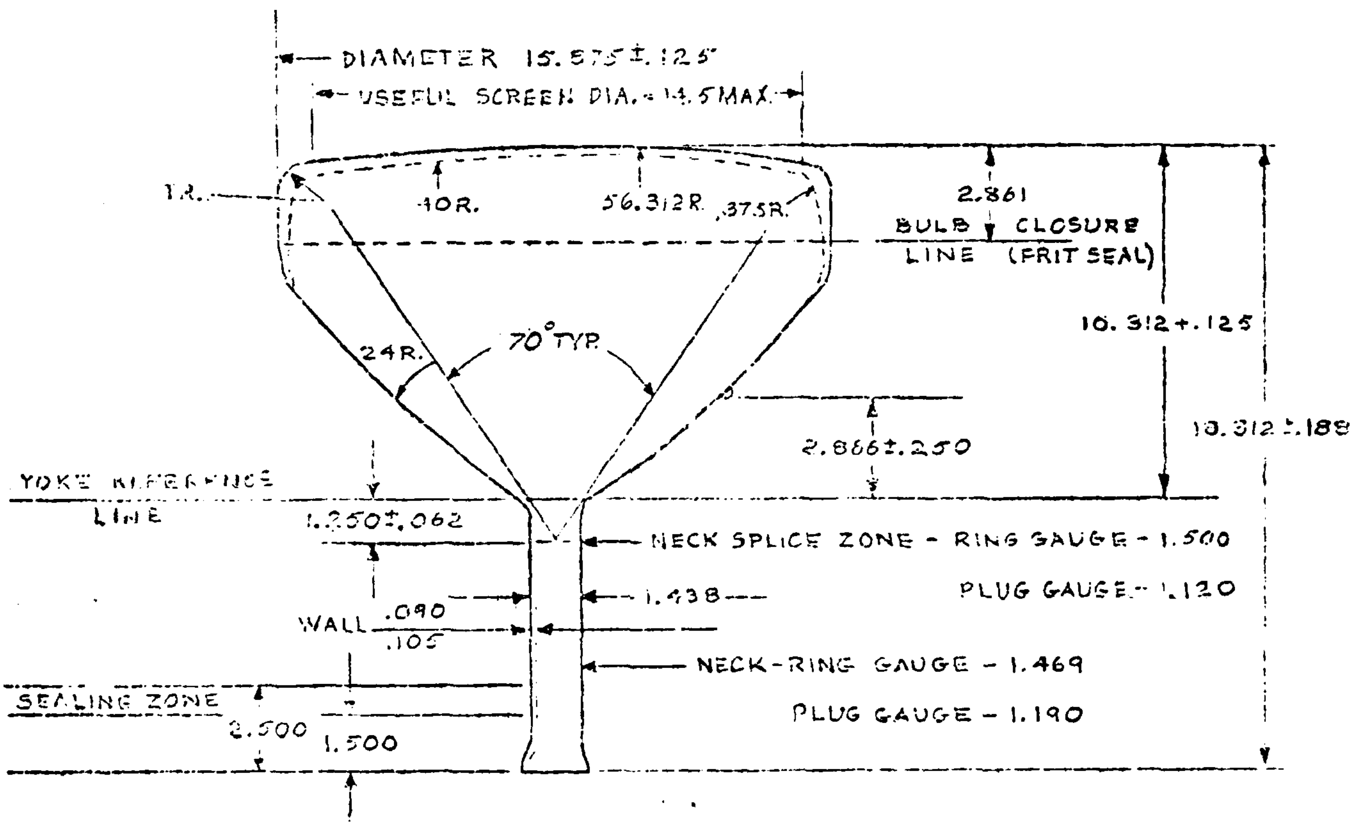
J127E1 BULB DRAWING



ALL DIMENSIONS IN INCHES

FIGURE 1

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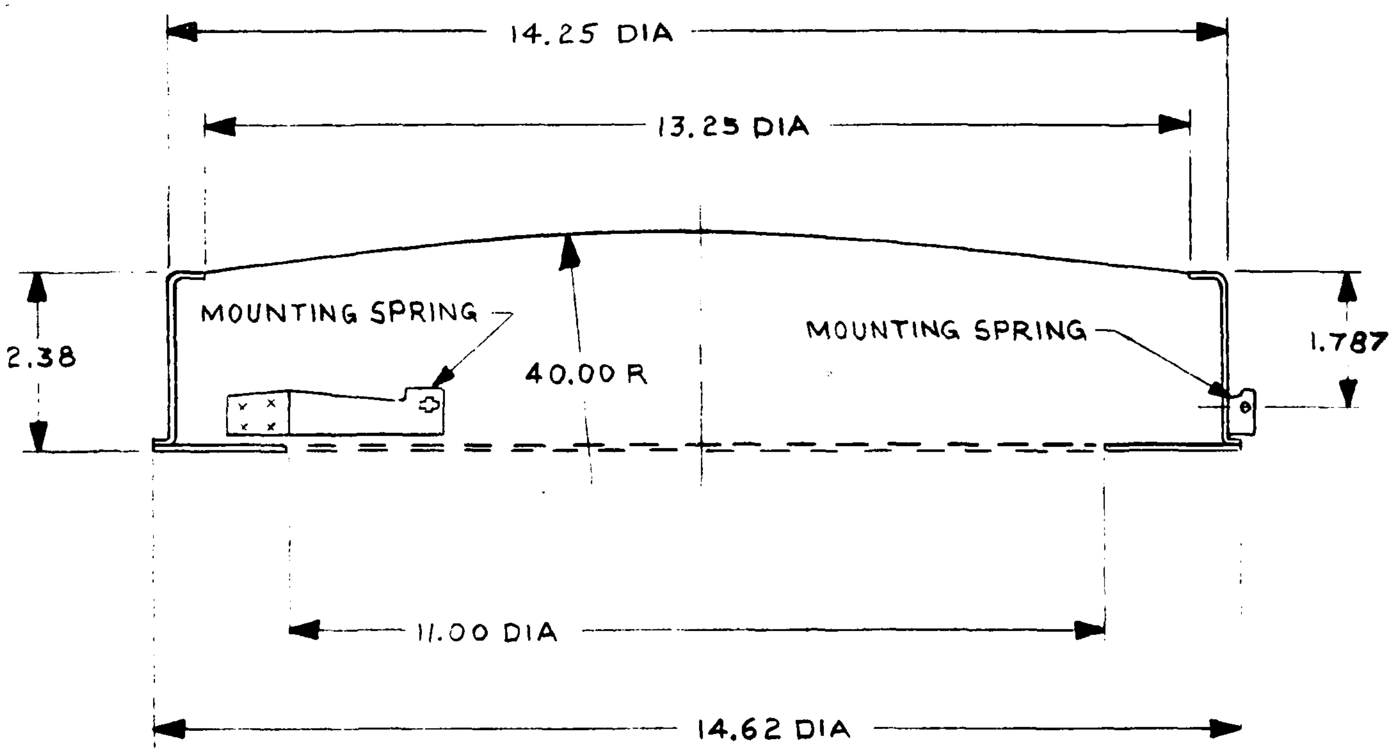

MESH – RING FRAME ASSEMBLY

ALL DIMENSIONS IN INCHES

FIGURE 2

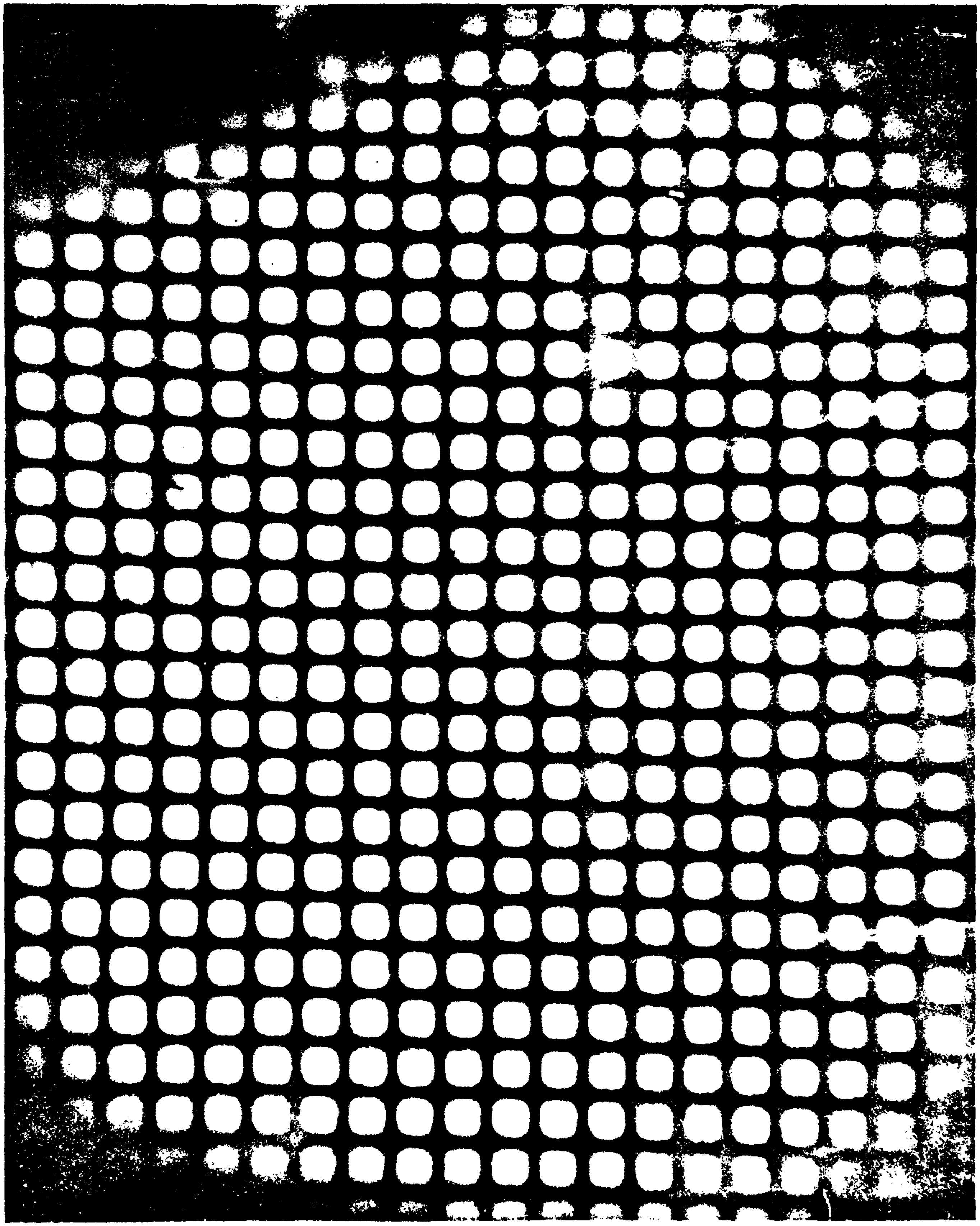

Figure 3 - Micro-Photo of the Mesh

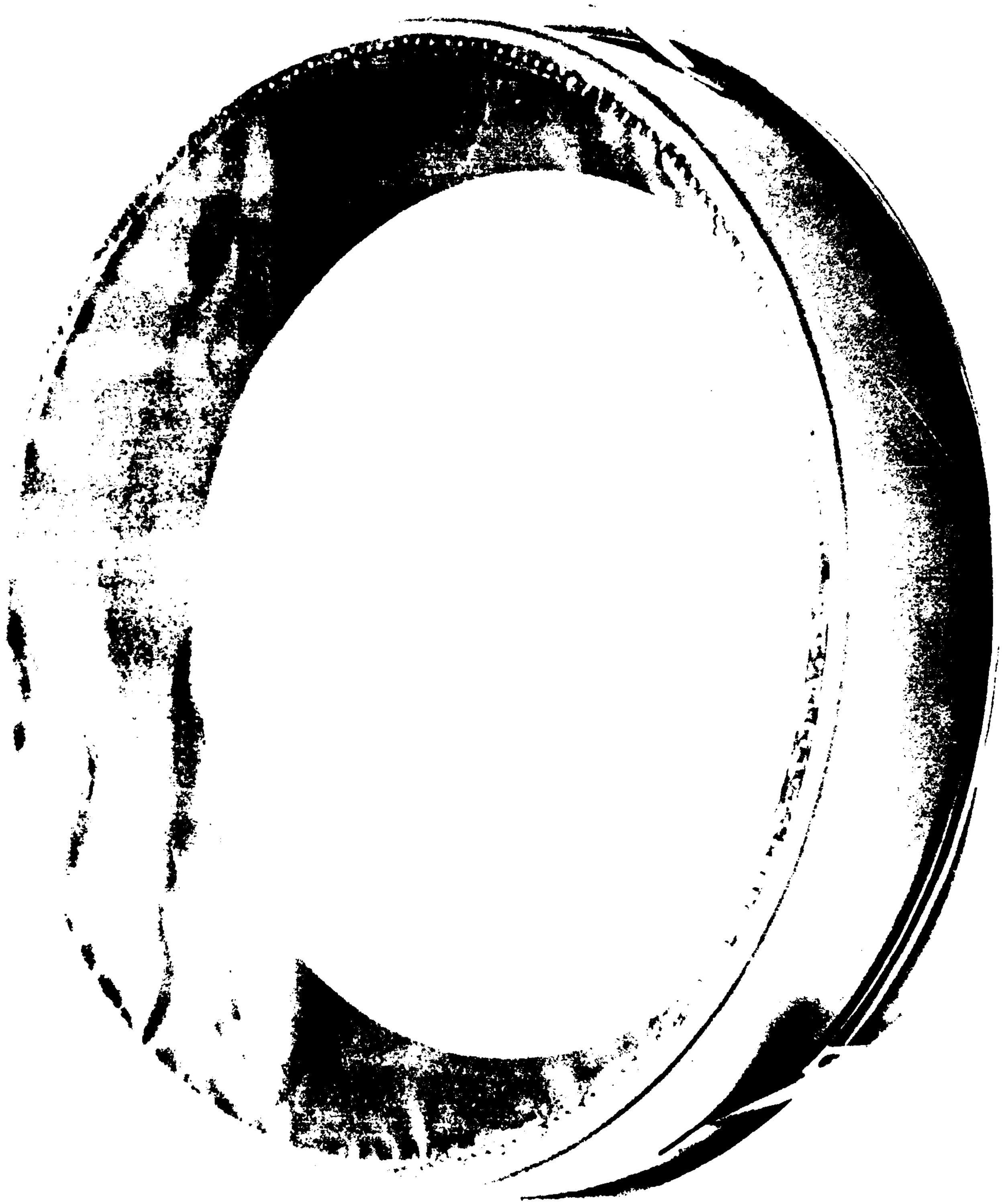

Figure 4 - Mesh-Ring frame assembly

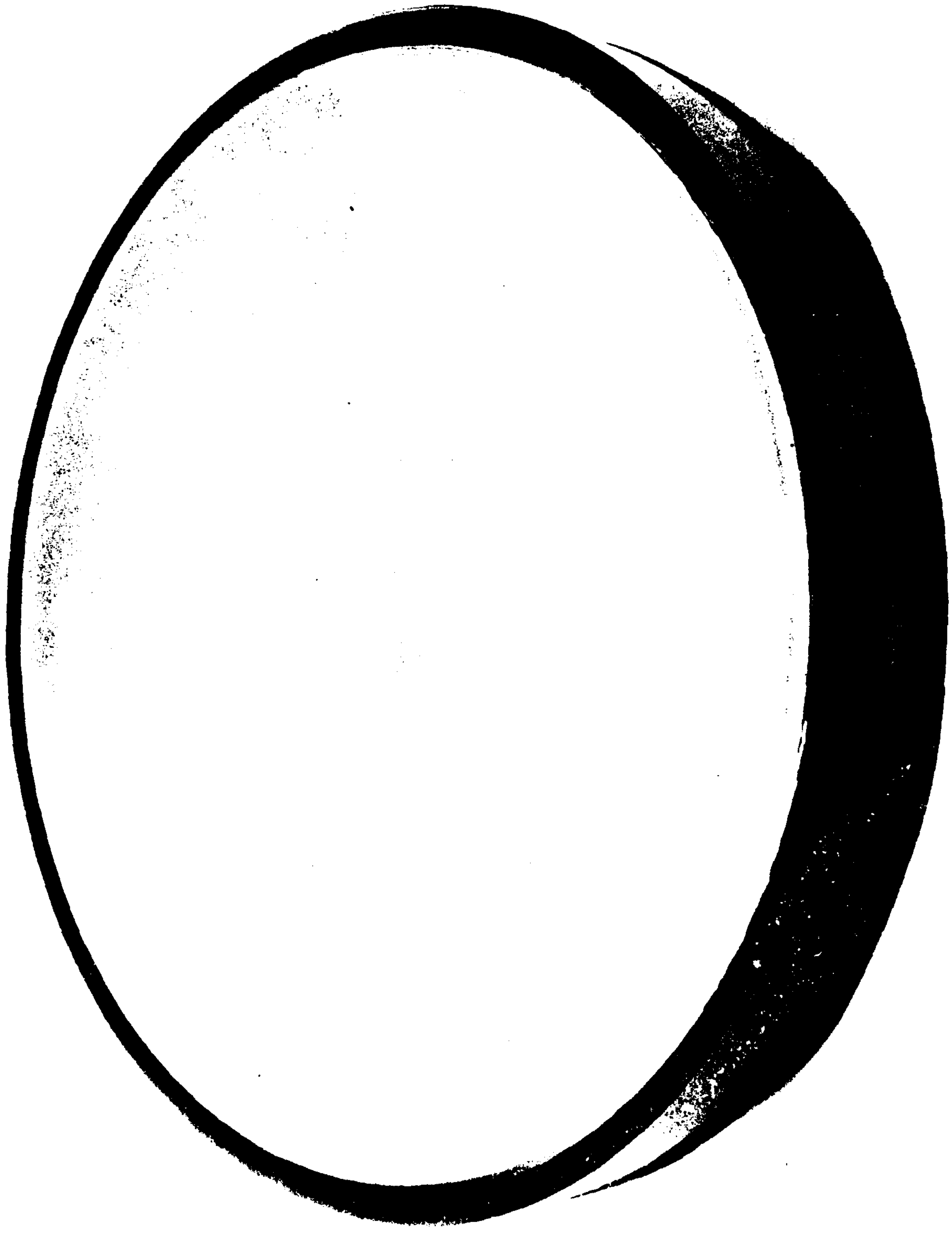

Figure 5 - Upper bulb (panel) assembly

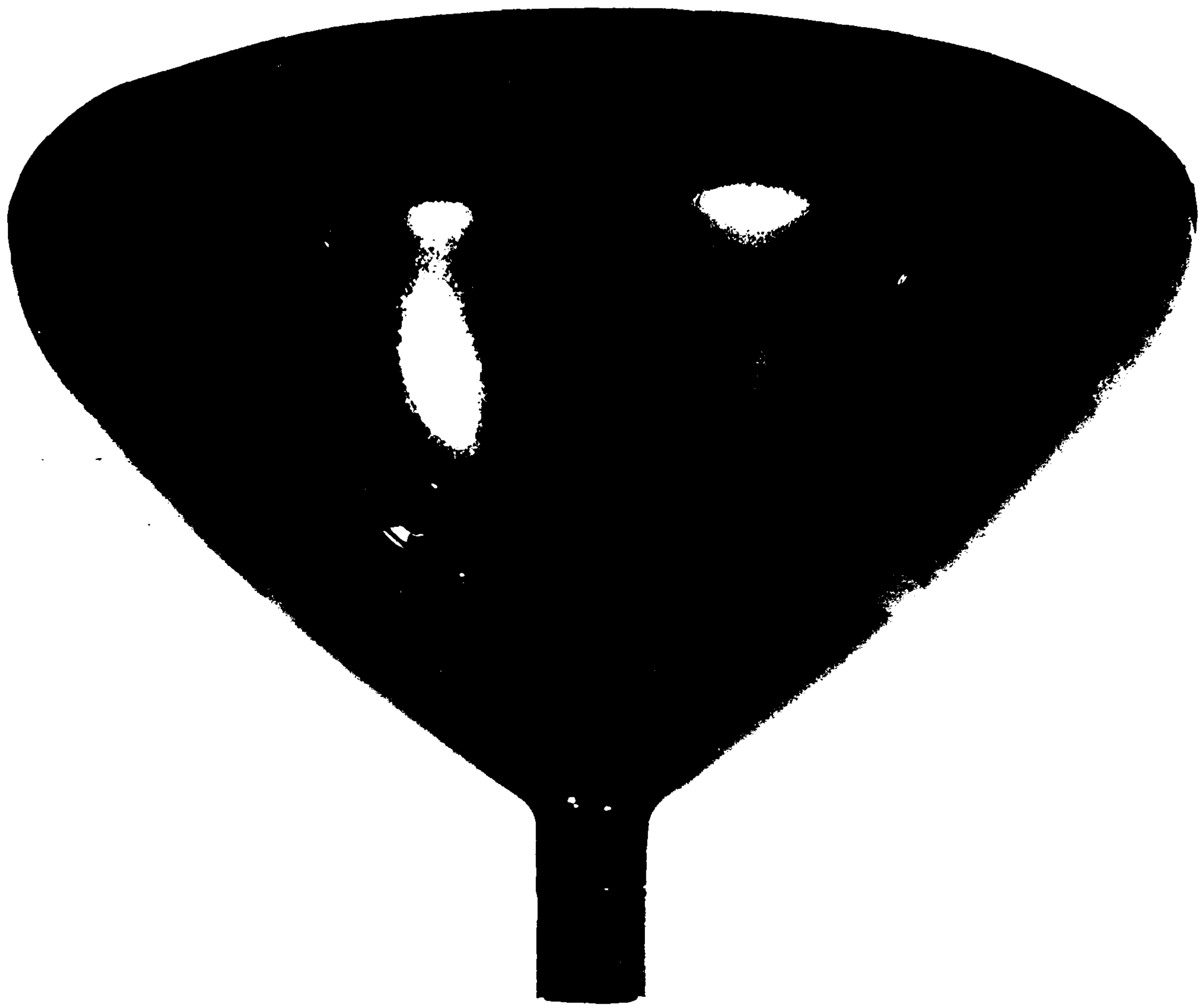

Figure 6 - Lower Bulb (funnel) assembly

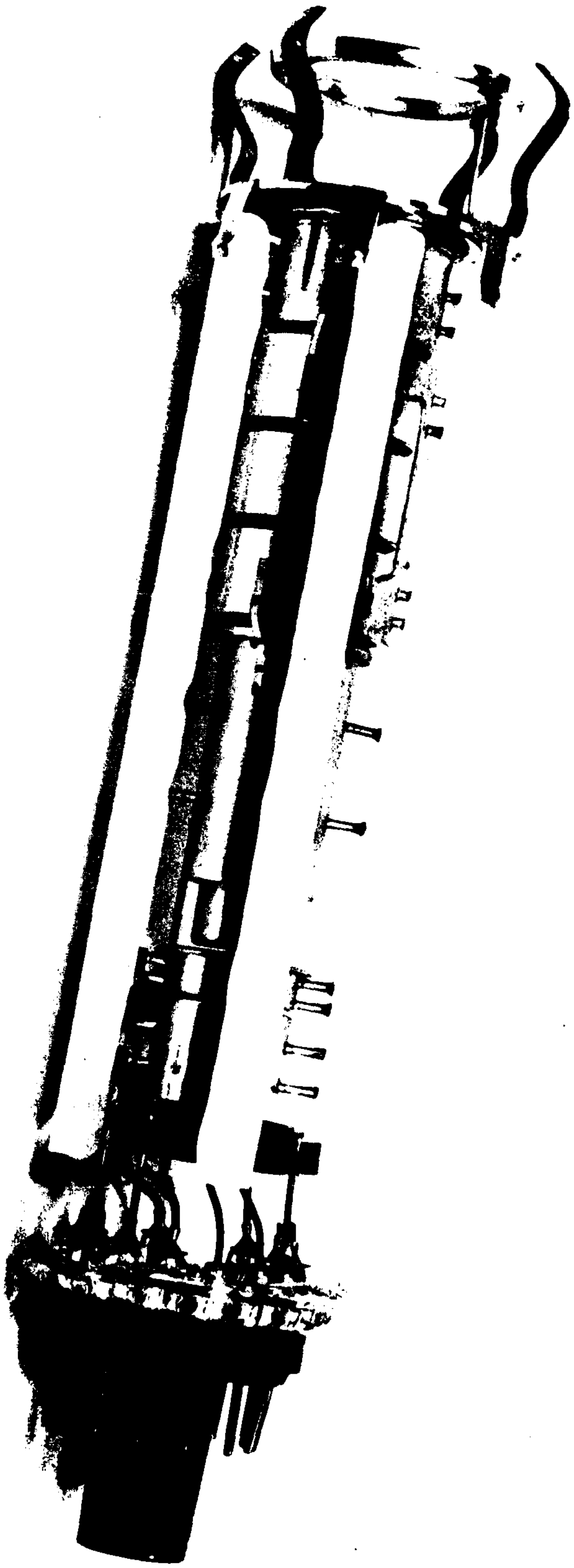

Figure 7 - Electron-gun mount assembly

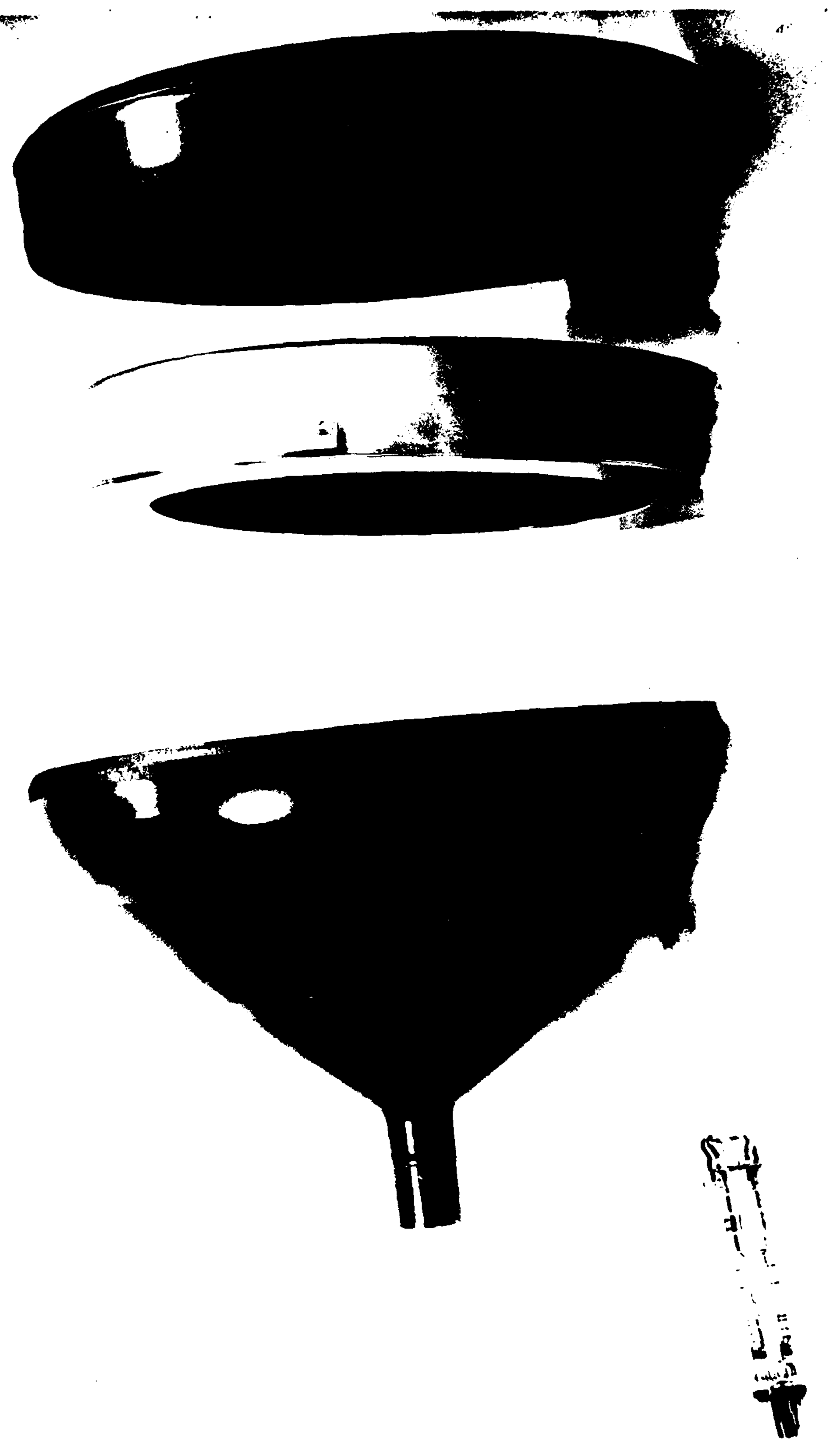

Figure 8 - Pre-assembly view of 16M100 CRT

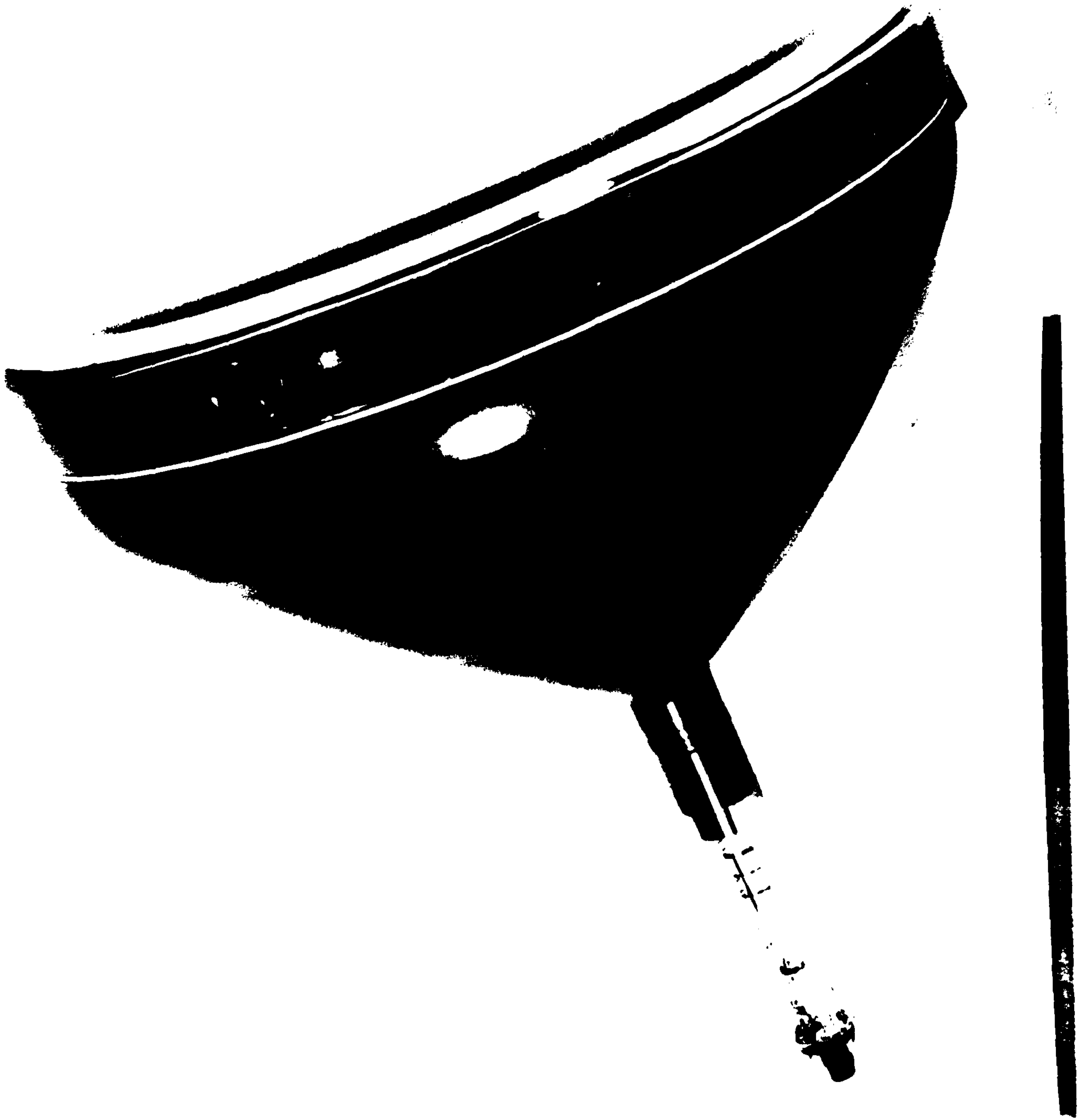

Figure 9 - Complete 16M100 CRT

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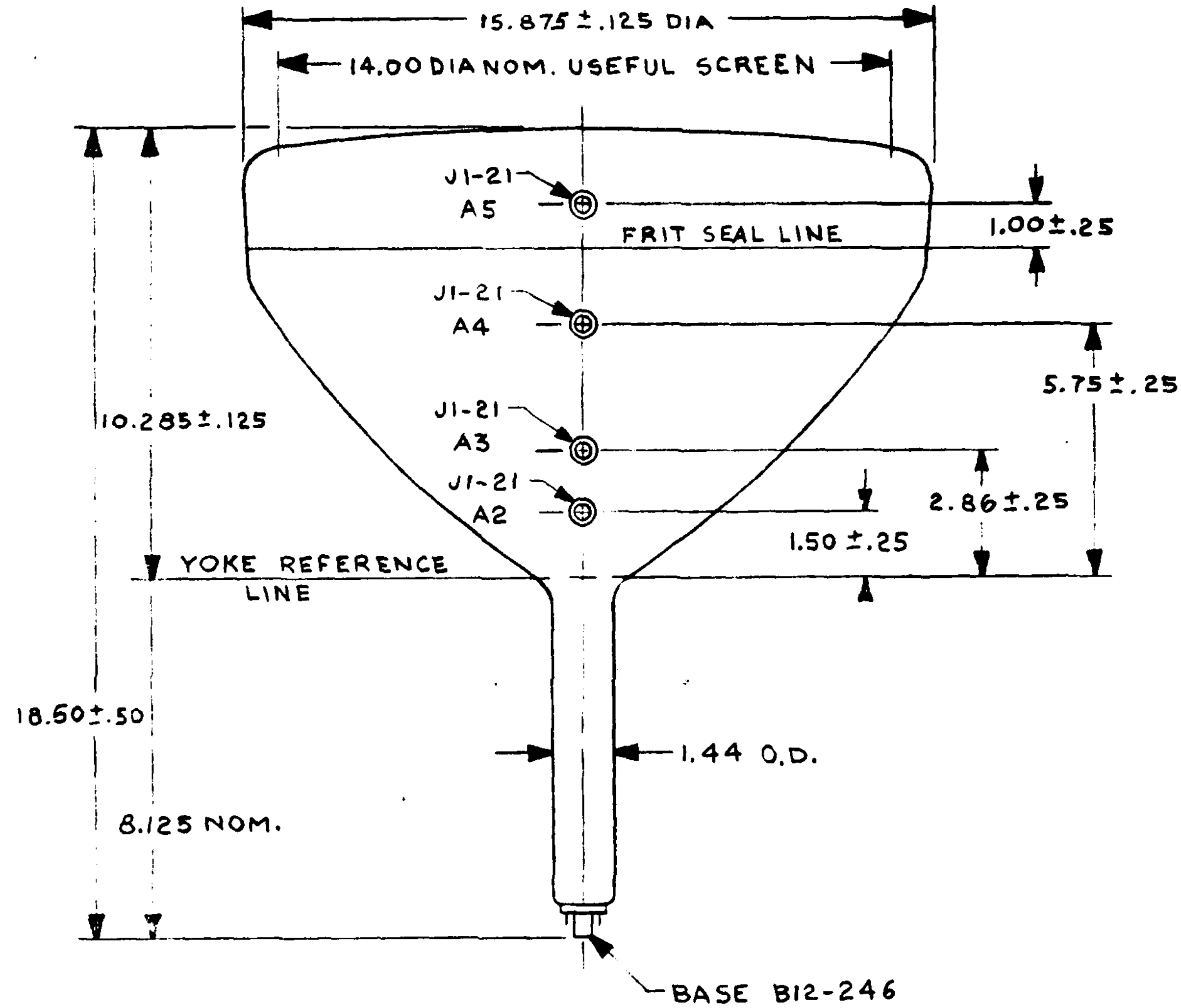
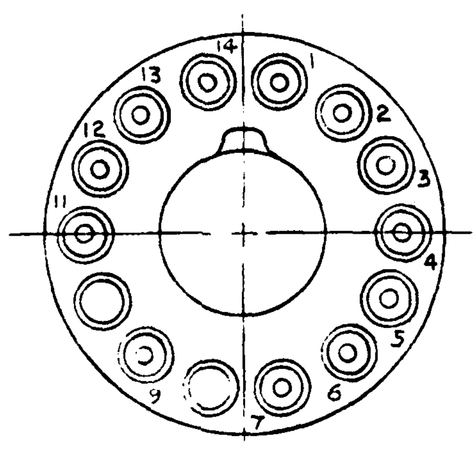
16M100P



BOTTOM VIEW OF BASE



ALL DIMENSIONS IN INCHES

PIN NO.	ELEMENT
1	CATHODE
2	HEATER
3	HEATER
4	GRID NO. 1
9	A1 (FOCUS)
13	GRID NO. 2

FIGURE 10

RELEASED	9-5-75
REVISED	

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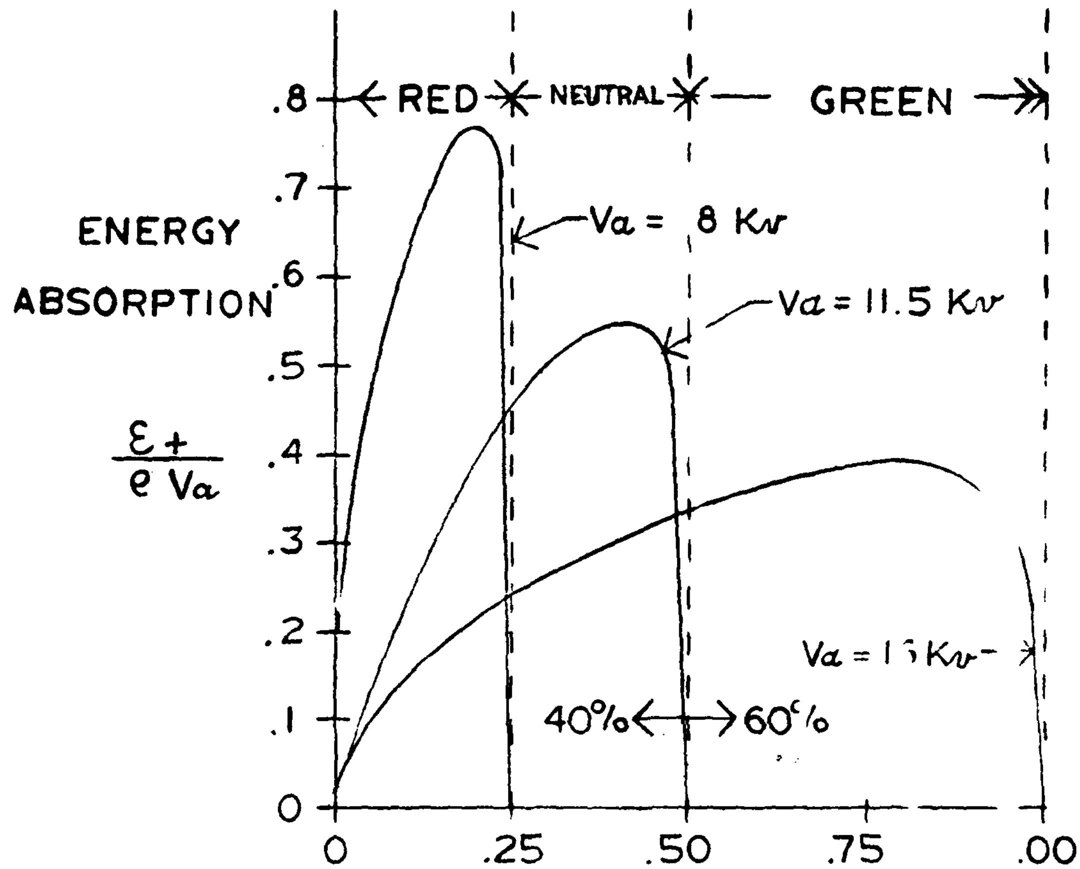


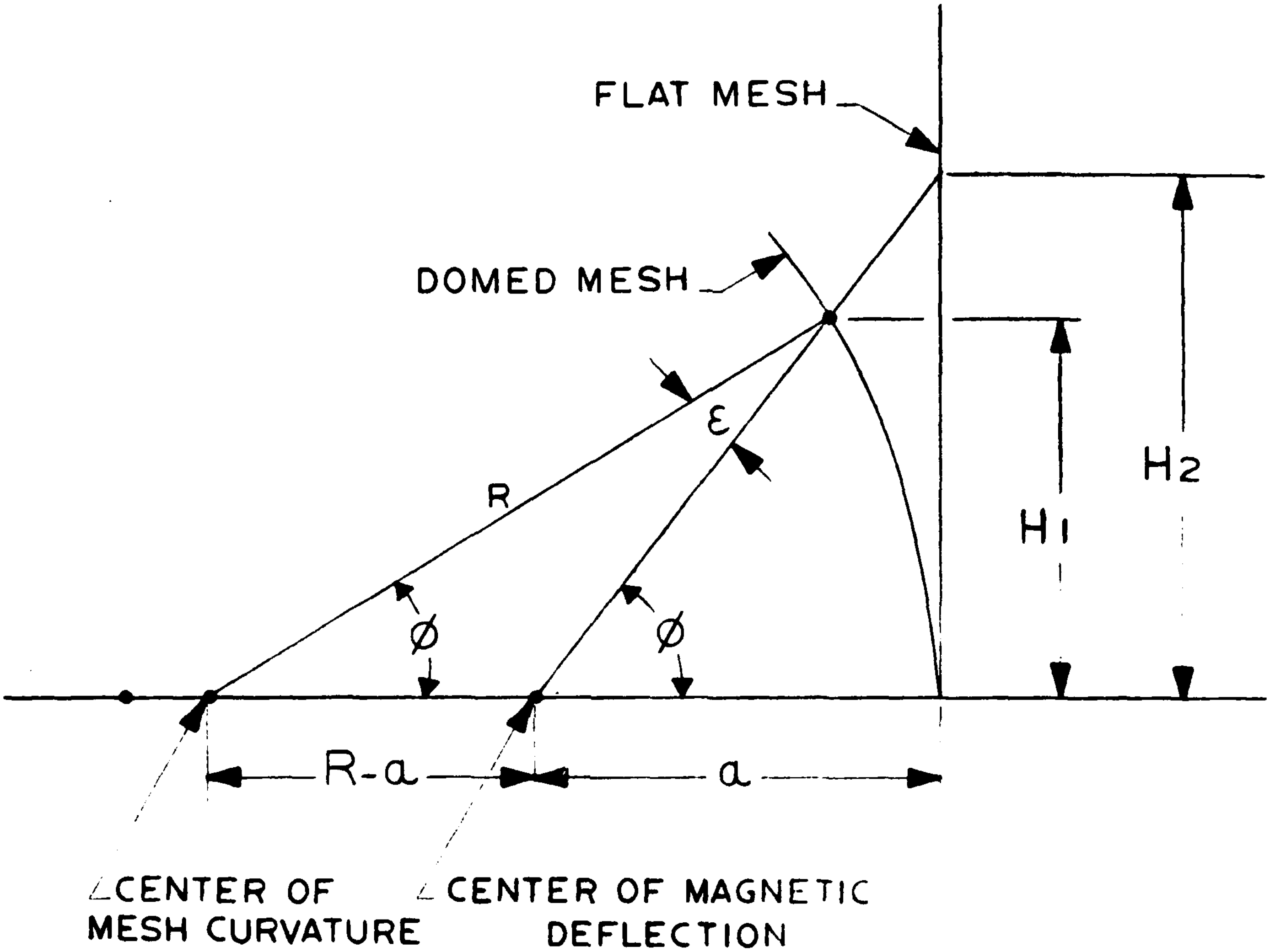
$\frac{x}{e}$ = PENETRATION DEPTH

$$e \approx \frac{k}{d} V_a^2$$

FIGURE 11

NOTE: ENERGY DIVISION FROM RED TO GREEN EXCITATION, ESTIMATED.

(PLEASE INCLUDE A LIST IDENTIFYING THE SYMBOLS USED.)



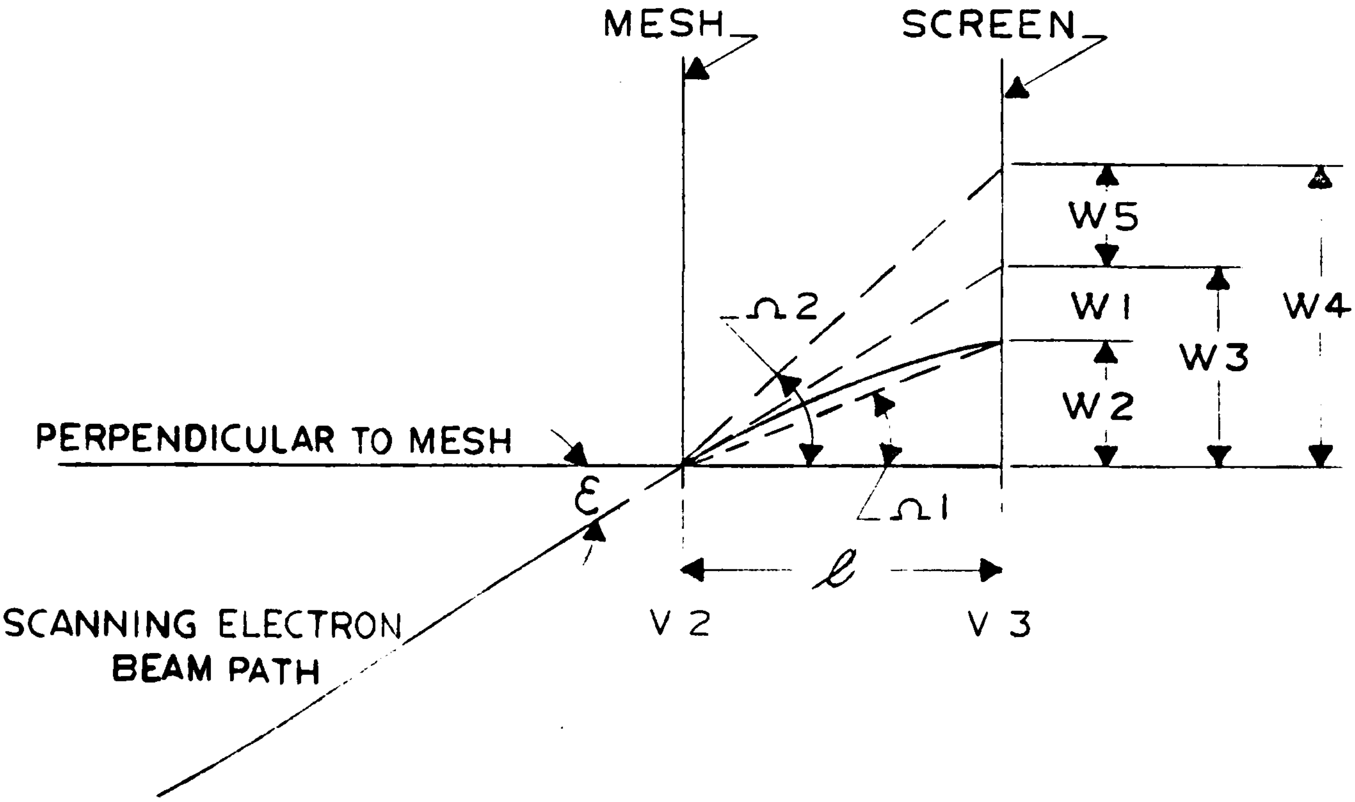
$$H_1 = \sin\phi\left\{\left[(R-a)^2\cos^2\phi + 2aR - a^2\right]^{1/2} - (R-a)\cos\phi\right\}$$
FOR THE DOMED MESH

$$H_2 = a\tan\phi$$
FOR THE FLAT MESH

ELECTRON-BEAM INTERCEPT ON THE MESH

FIGURE 12

SMALL AREA, MESH-TO-SCREEN SECTION



$$W3 = \ell \tan \varepsilon$$

RADIAL DECREASE

$$\downarrow W2 = \frac{2\ell \sin \varepsilon}{\frac{V3}{V2} - 1}\left[\left(\frac{V3}{V2} - \sin^2 \varepsilon\right)^{1/2} - \cos \varepsilon\right] = W4 \uparrow$$

RADIAL INCREASE

$W1 = W3 - W2$ = ACCELERATION DIFFERENCE WHEN $\frac{V3}{V2} > 1$

$W5 = W4 - W3$ = RETARDATION DIFFERENCE WHEN $\frac{V3}{V2} < 1$

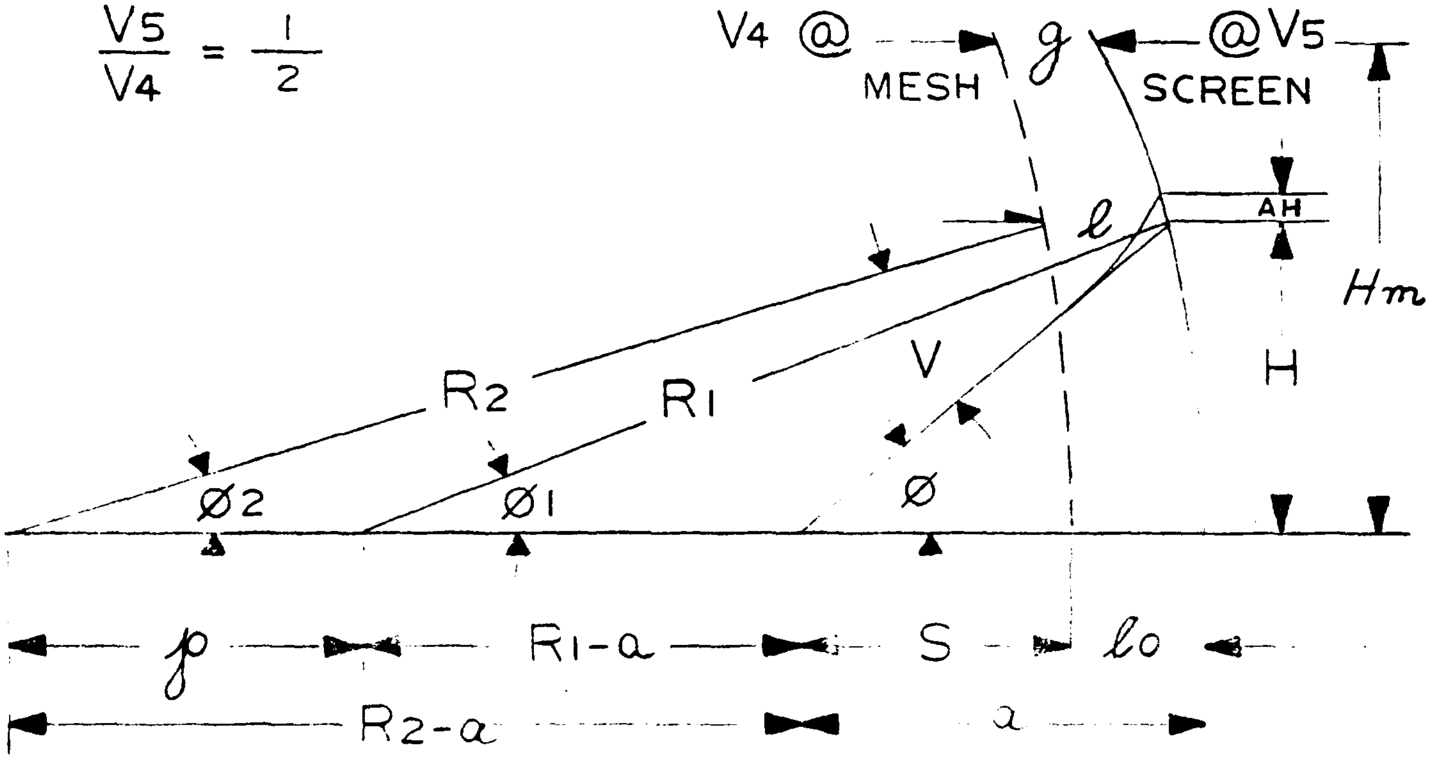
SMALL AREA, MESH-TO-SCREEN GEOMETRY

FIGURE 13

$R_1 = 40$ INCHES $\quad \ell_o = .50$ INCHES

$R_2 = 60$ INCHES $\quad H_m = 7.0$ INCHES

$$\frac{V_5}{V_4} = \frac{1}{2}$$



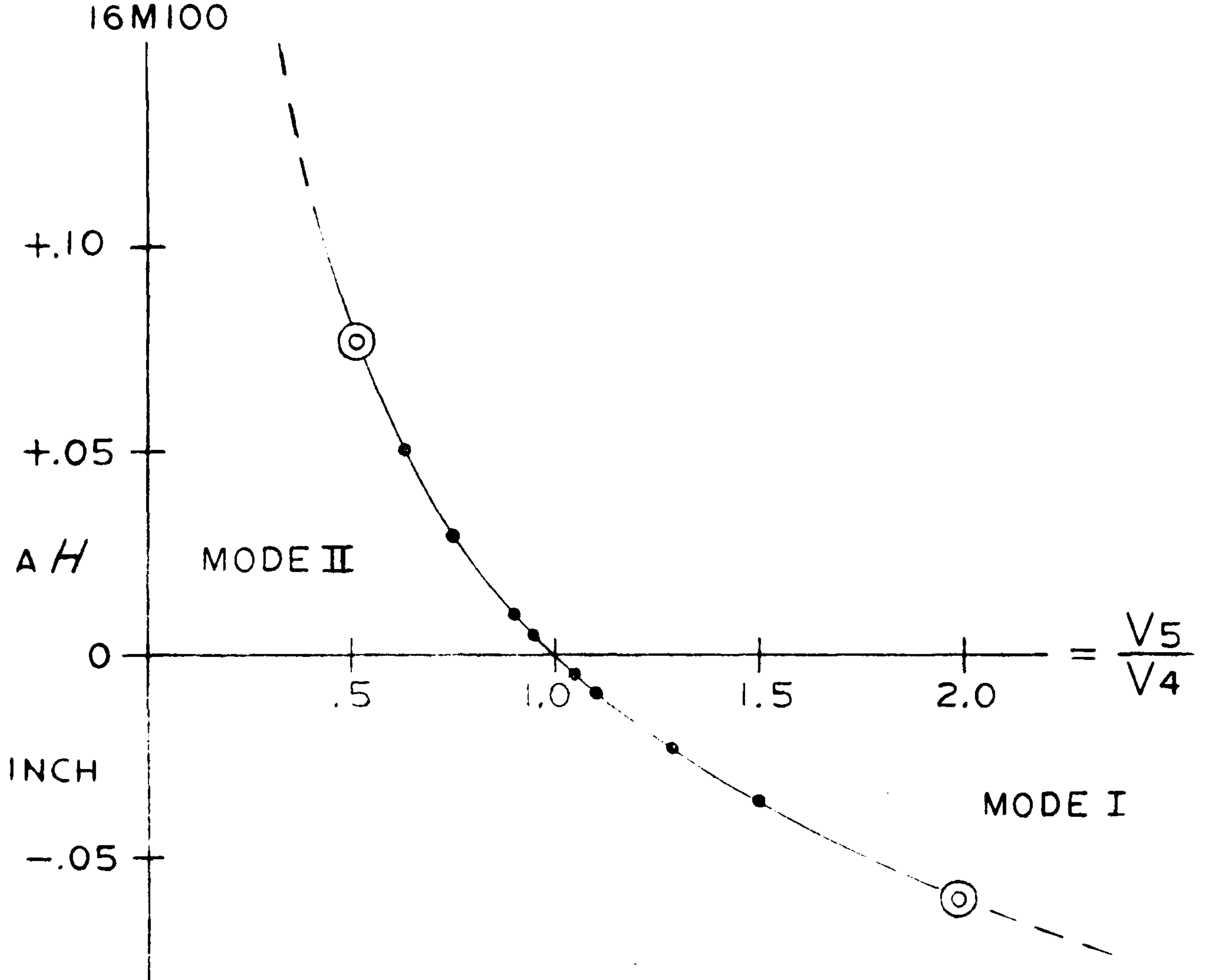
$$\ell = \ell_o - R_1 + R_2 + (R_1^2 - H^2)^{1/2} - (R_2^2 - H^2)^{1/2}$$

$$\ell = \ell_o \text{ AT } H = 0 \qquad = \quad 0.50 \text{ INCHES}$$

$$\ell = g \text{ AT } H = H_m \qquad = \quad 0.29 \text{ INCHES}$$

COLOR SWITCHED BEAM-LOCATION ON SCREEN

FIGURE 14



$$\Delta H = \frac{2\ell \sin\phi}{V5/V4 - 1}\left[\left(V5/V4 - \sin\phi\right)^{1/2} - \cos\phi\right] - \ell \tan\phi$$

$\ell = .5$ INCH AND $\phi = 30°$

COLOR-SWITCHED
DISPLAY-DEPOSITIONING

FIGURE 15

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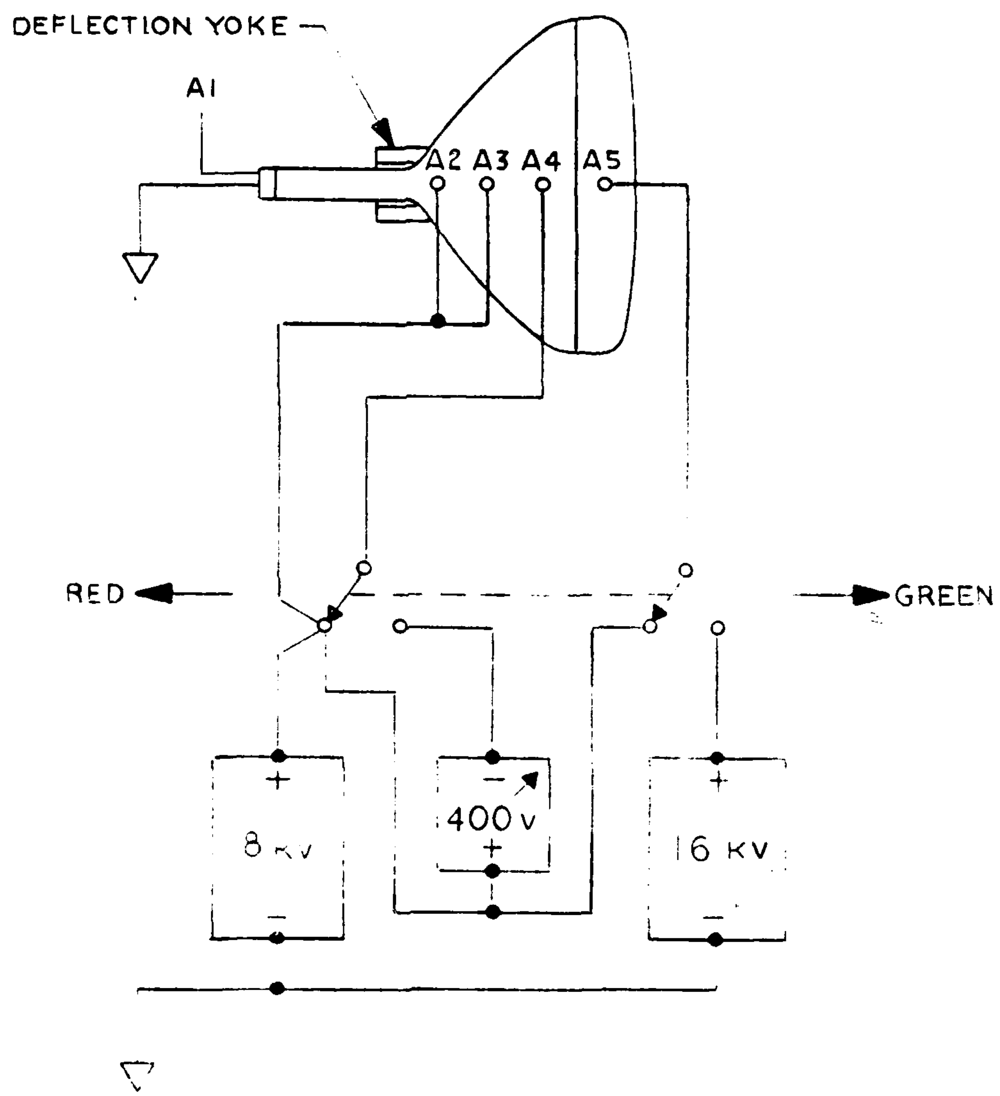
ELECTRONICS, INC. 16M100

NO. I MODE



PENETRATION - PHOSPHOR COLOR CATHODE-RAY TUBE

ANODE SWITCHING SCHEMATIC

FIGURE 16 a

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THOMAS
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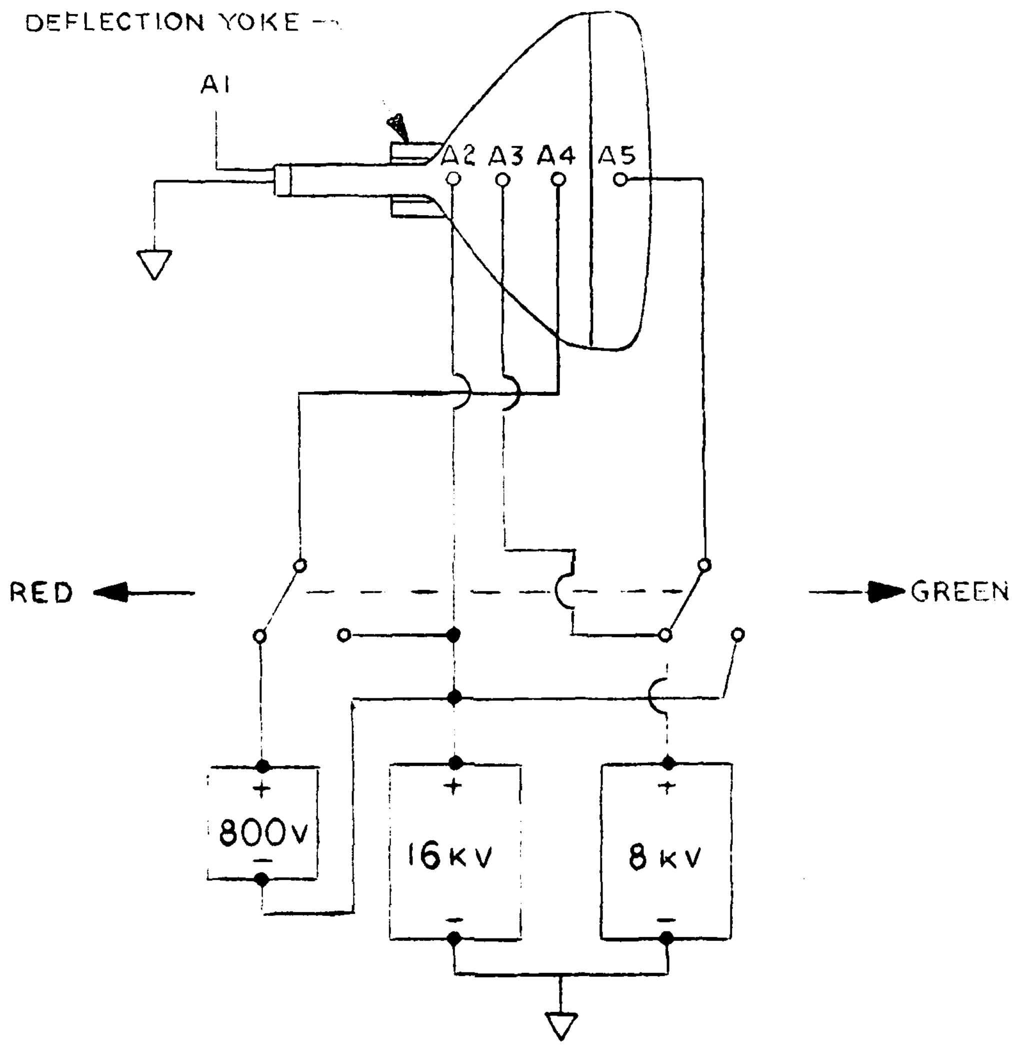
NO. II MODE

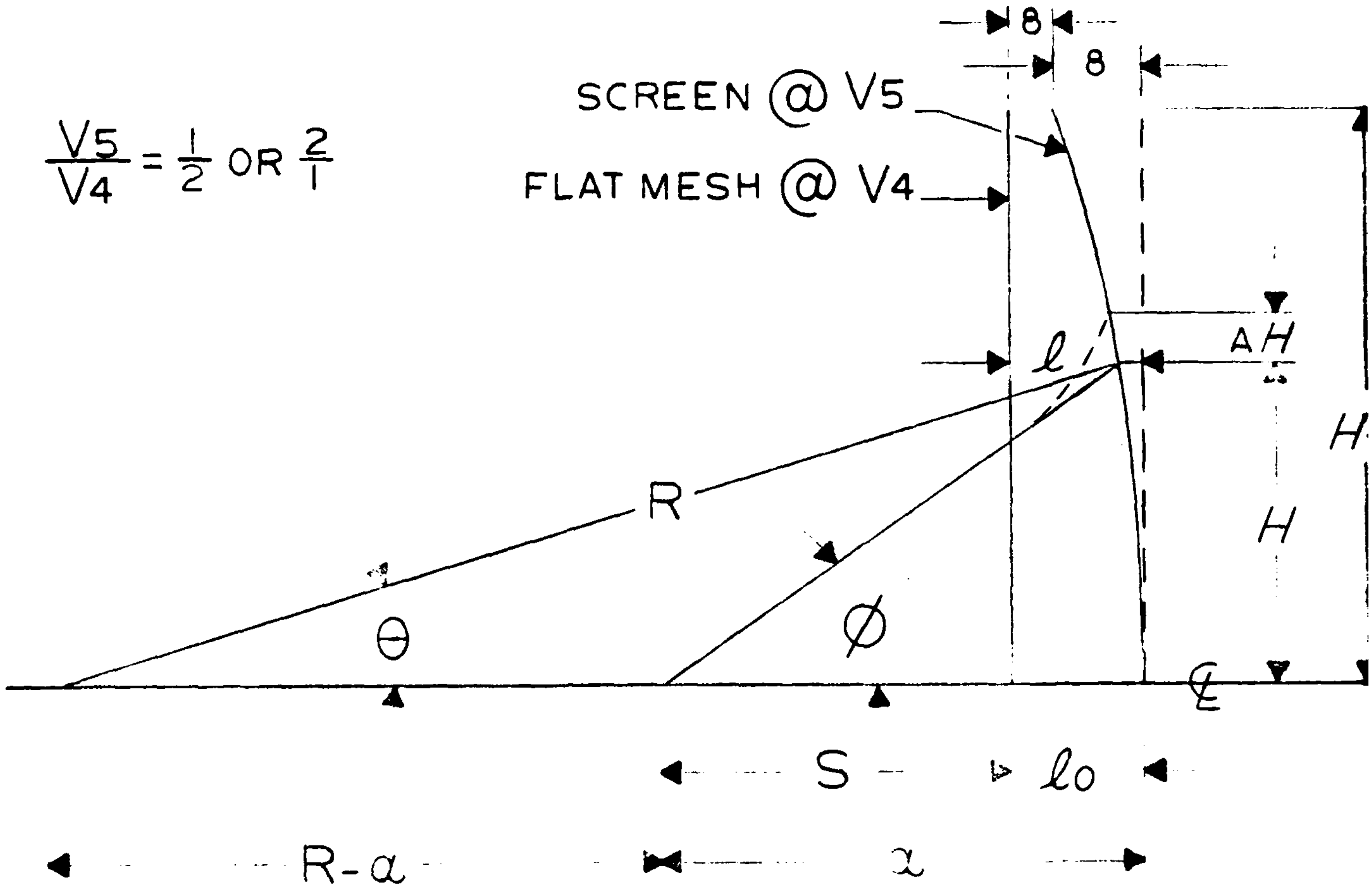


PENETRATION-PHOSPHOR COLOR CATHODE-RAY TUBE

ANODE SWITCHING SCHEMATIC

FIGURE 16 b

$$\frac{V5}{V4} = \frac{1}{2} \text{ OR } \frac{2}{1}$$



SCREEN = R RADIUS OF CURVATURE

$$\varnothing = \text{ARCTAN } \frac{H}{S+\ell}$$

$$\ell = \ell o + \left(R^2 - H^2\right)^{1/2} - R$$

$$g = \ell o + \left(R^2 - H_m^2\right)^{1/2} - R$$

α = DEFLECTION "RADIUS OF CURVATURE"

$\ell o - g = z =$ .245 INCH @ ℓ = 100 INCHES $\approx \frac{H_m^2}{2R}$

.492	"	50	"
.617	"	40	"
1.000	"	25	"

FIGURE 17

THOMAS
ELECTRONICS, INC
100 RIVERVIEW DRIVE
WAYNE, N J 07470

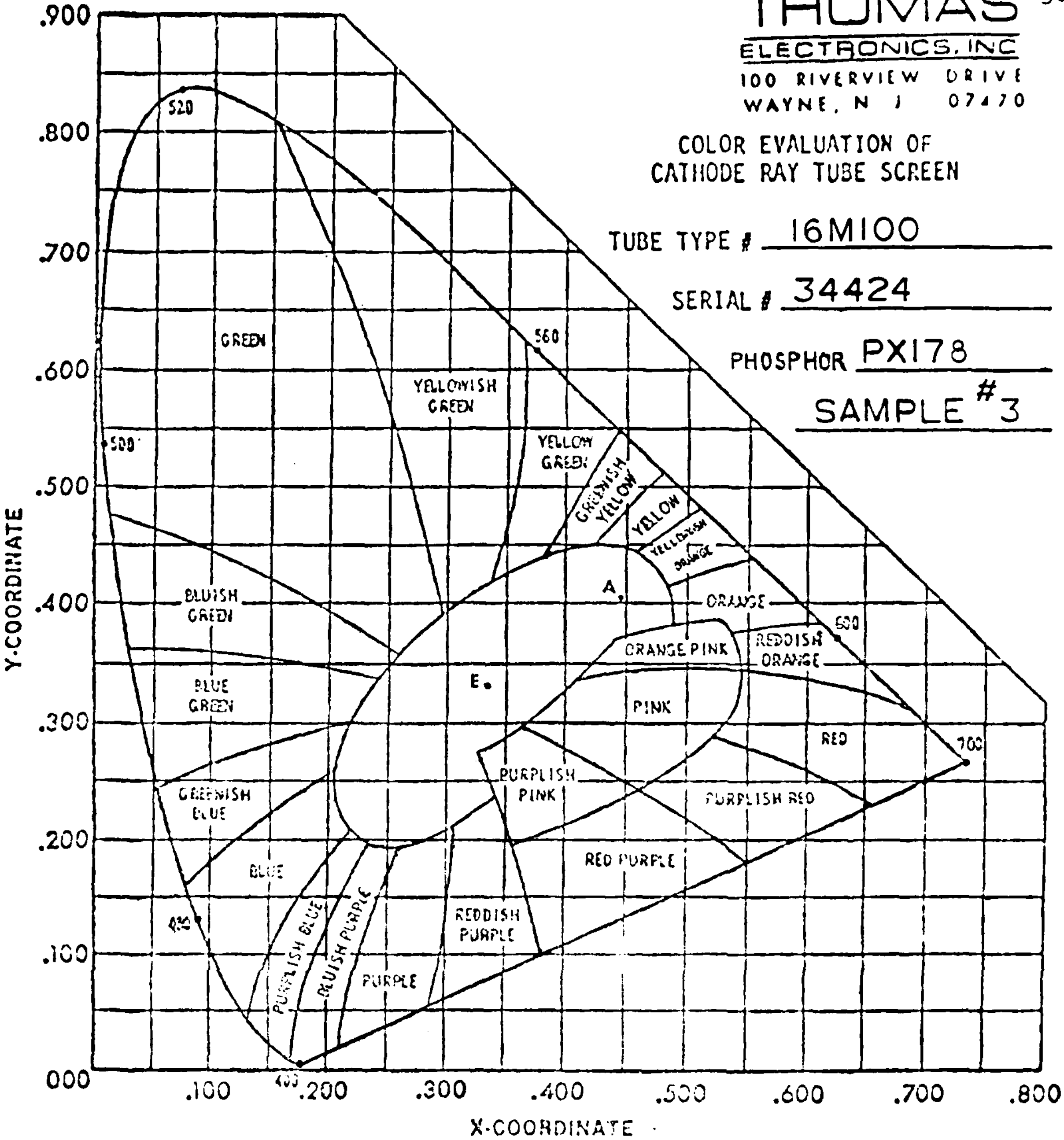
COLOR EVALUATION OF
CATHODE RAY TUBE SCREEN

TUBE TYPE # 16M100

SERIAL # 34424

PHOSPHOR PX178

SAMPLE #3



ANODE VOLTAGE (KV)	SCREEN CURRENT (ma)	x	y	FOOT LAMBERTS 10"X10"			
16	0.1	.371	.553	6.8			
12	0.1	.471	.466				
8	0.1	.576	.370	0.75			

FIG. 18

THOMAS
ELECTRONICS, INC
100 RIVERVIEW DRIVE
WAYNE, N J 07470

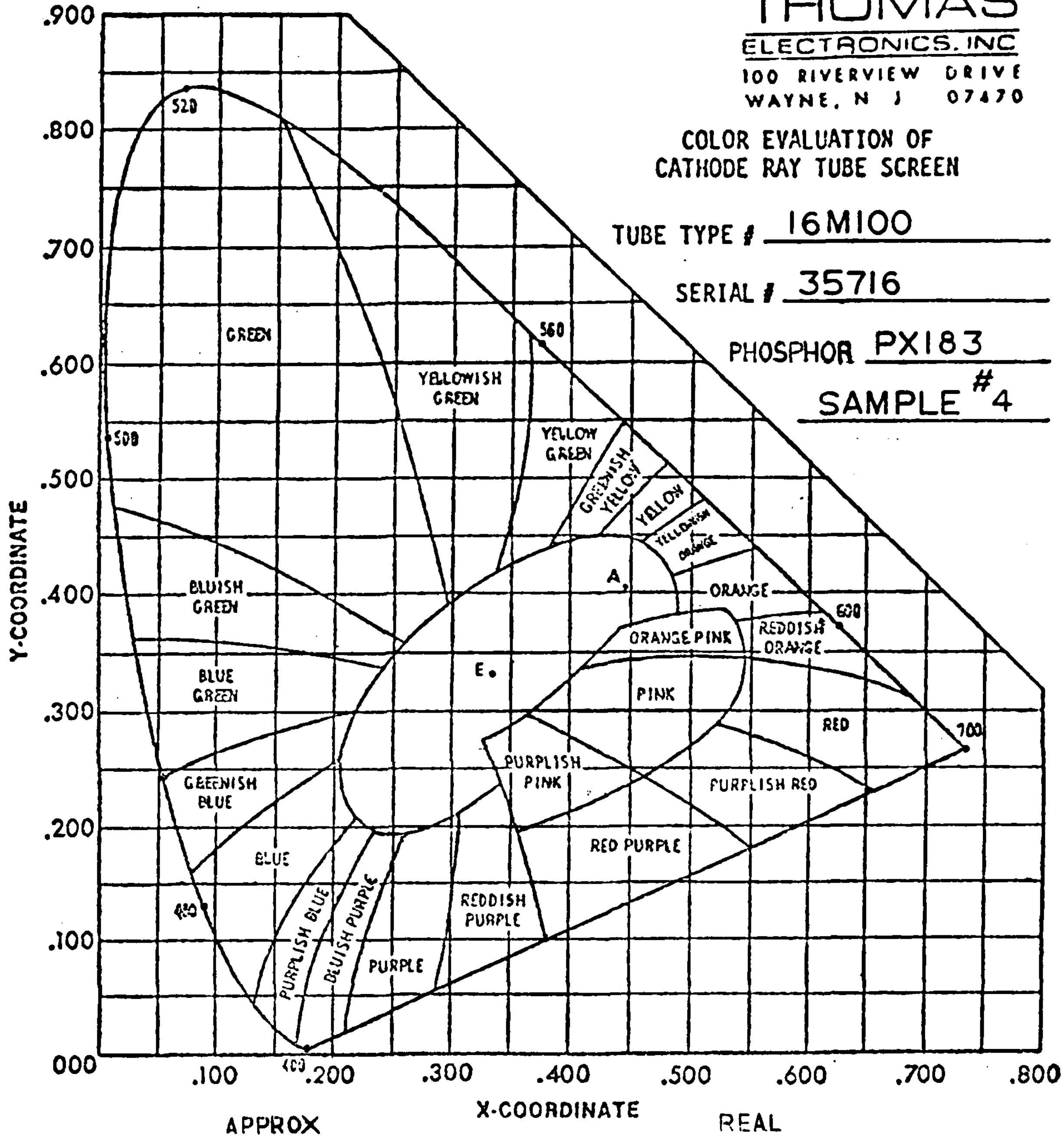
COLOR EVALUATION OF
CATHODE RAY TUBE SCREEN

TUBE TYPE # 16M100

SERIAL # 35716

PHOSPHOR PX183

SAMPLE #4



	APPROX				REAL		
ANODE VOLTAGE (KV)	SCREEN CURRENT (ma)	x	y	FOOT LAMBERTS 10"×10"	SCREEN CURRENT (ma)		
16	0.1	.398	.522	14.0	74		
.12	0.1	.483	.460	4.4	74		
8	0.1	.592	.371	1.2	74		

FIG. 19

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